(5) During the resting time, the anti-T-R spark gap is not broken down by the received signals, so that the input to the cavity is practically an open circuit. This is reflected to the main guide as an open circuit. The received signals are in effect turned back by the apparent open circuit at the mouth of the anti-T-R branch setting up reflections which a quarter-wave away at the T-R branch produce a short or closing of the main guide. The signals are directed into the T-R branch where they pass through the resonant cavity to the receiver.

(6) Instead of using resonant cavities and T-R tubes, the branch waveguides can use resonant slots which also act as spark gaps (fig. 175). The resonant slot is a partition across the guide with an aper-

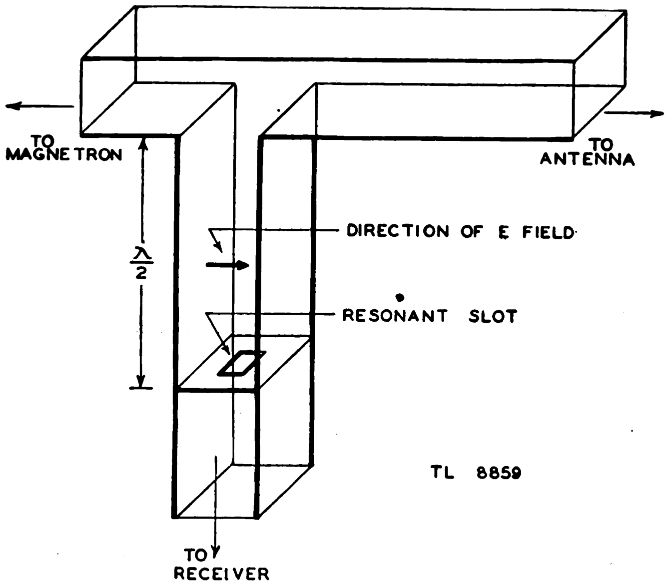

Figure 175. Slot type T-R switch.

ture whose dimensions make it look like a parallel resonant circuit at the carrier frequency. The dimension in the direction of the electric field is made small so that the transmitted pulse will cause an arc. The arc closes the conducting surface of the slot, providing a short circuit which is reflected by the half-wave line to the main guide.

39. LOBE SWITCHING.

a. Dual antennas. (1) The accuracy of angular measurement depends on the sensitivity of the antenna to a change in the direction of the arrival of the echo signals. In paragraph 5 the idea is discussed of using two patterns the axes of which are displaced from each other sufficiently to cause the patterns to cross over at less than

the 85 percent maximum signal point. The advantage which is obtained is that of comparing two signals whose changes in magnitude are great per degree change in azimuth, and whose directions of change are opposite. The operator is better able to select the correct on-target position of the antenna since he sets to a position which makes the two signals equal for the target being tracked.

(2) An antenna system which uses the double-lobe principle must include provisions for obtaining the two patterns displaced from each other, and some method for comparing the received signals from both lobes on the indicator. The simplest system is to use separate antennas, receivers, and a common indicator. It is more economical, however, to use a single receiver which can be switched between the lobes. Figure 176 shows the components of an elementary lobe-switching system.

(3) Separate antennas are mounted so that their patterns overlap, intersecting at approximately the half-power points. The feed line from the two antennas are brought to a double-pole double-throw switch. The switch alternately selects the signals from antenna 1 and then from antenna 2 to be amplified by the receiver. The output of the receiver is therefore a combination of the two groups of signals from the two antennas. These signals are separated by a single-pole double-throw switch so that they may be compared on the indicator. The two switches are thrown in synchronism by a switch motor.

(4) The sequence of events in the lobe-switching operation is shown in figure 177. The echo signal from the target (fig. 176) induces a smaller voltage in antenna 1 than antenna 2. It is assumed that system PRF is four times the switching frequency, so that two pulses are received while the receiver is connected to antenna 1, and two while the receiver is connected to antenna 2. Starting from the instant that the switch moves to the antenna 1 position, the receiver amplifies two cycles of echo signals from antenna 1, and then switches to antenna 2 for two cycles. Thus the output of the receiver is a series of pulses that are alternately proportional to signals received by antenna 1 and then to signals received by antenna 2. The indicator output switch separates the pulses by placing those from antenna 1 on the left deflecting plate, and those from antenna 2 on the right deflecting plate.

(5) During the time that signals from antenna 1 are being applied to the indicator, the right deflecting plate is effectively grounded, and the trace produced is shown by figure 178①. When the switch is moved to antenna 2, the left deflecting plate is grounded, and the indication is as in ②. The indicator cathode-ray-tube screen has sufficient persistence so that when the switch motor runs at normal speed, the two traces appear simultaneously as in ③. The operator

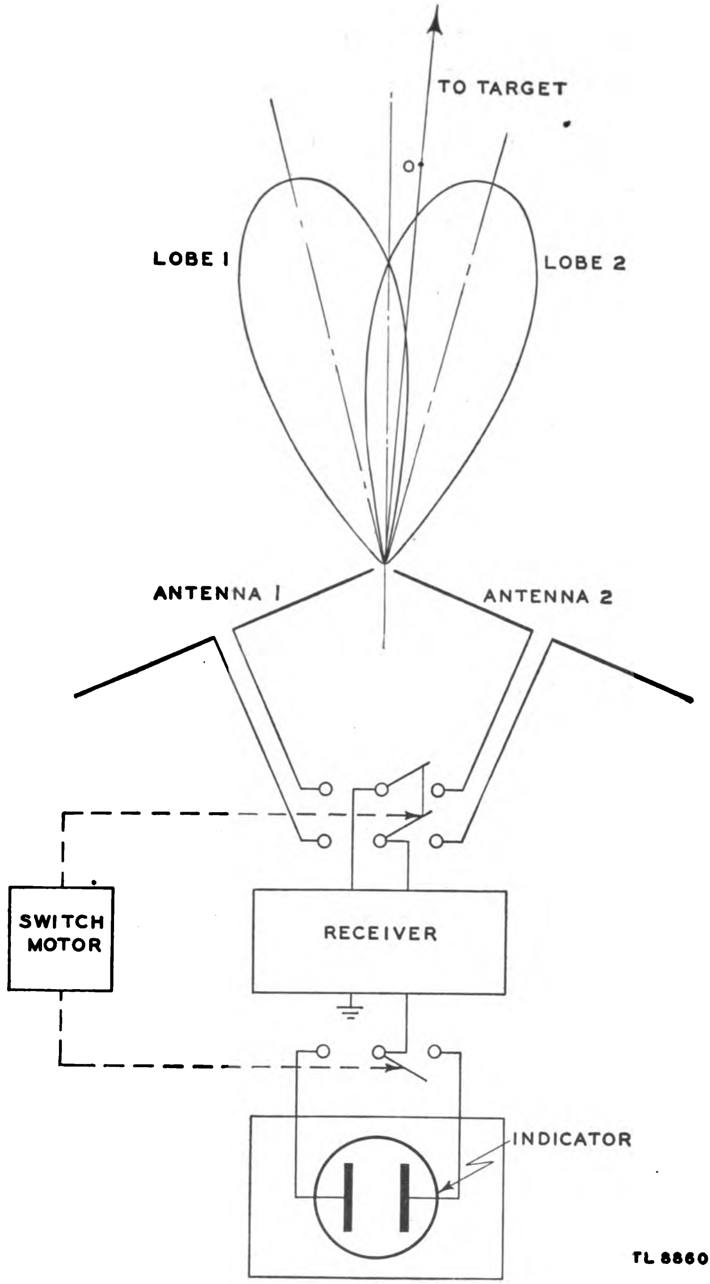

Figure 176. Mechanical lobe switch.

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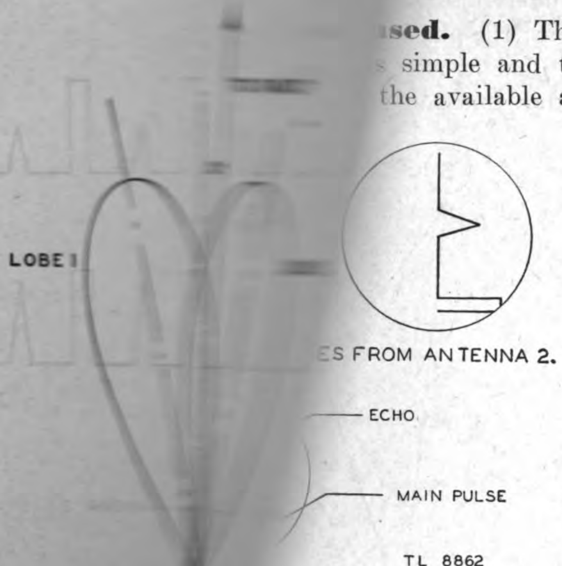
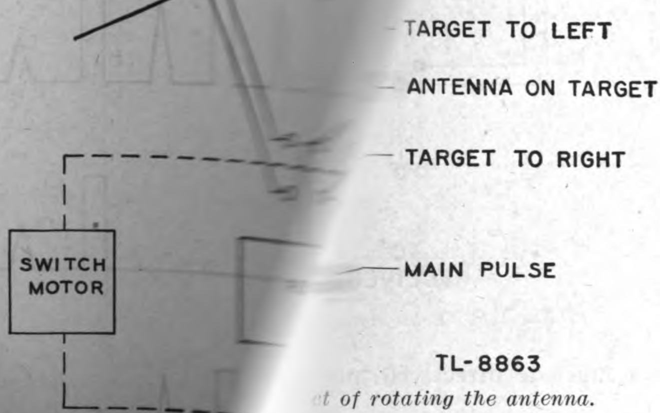


PICTURE

scope picture.



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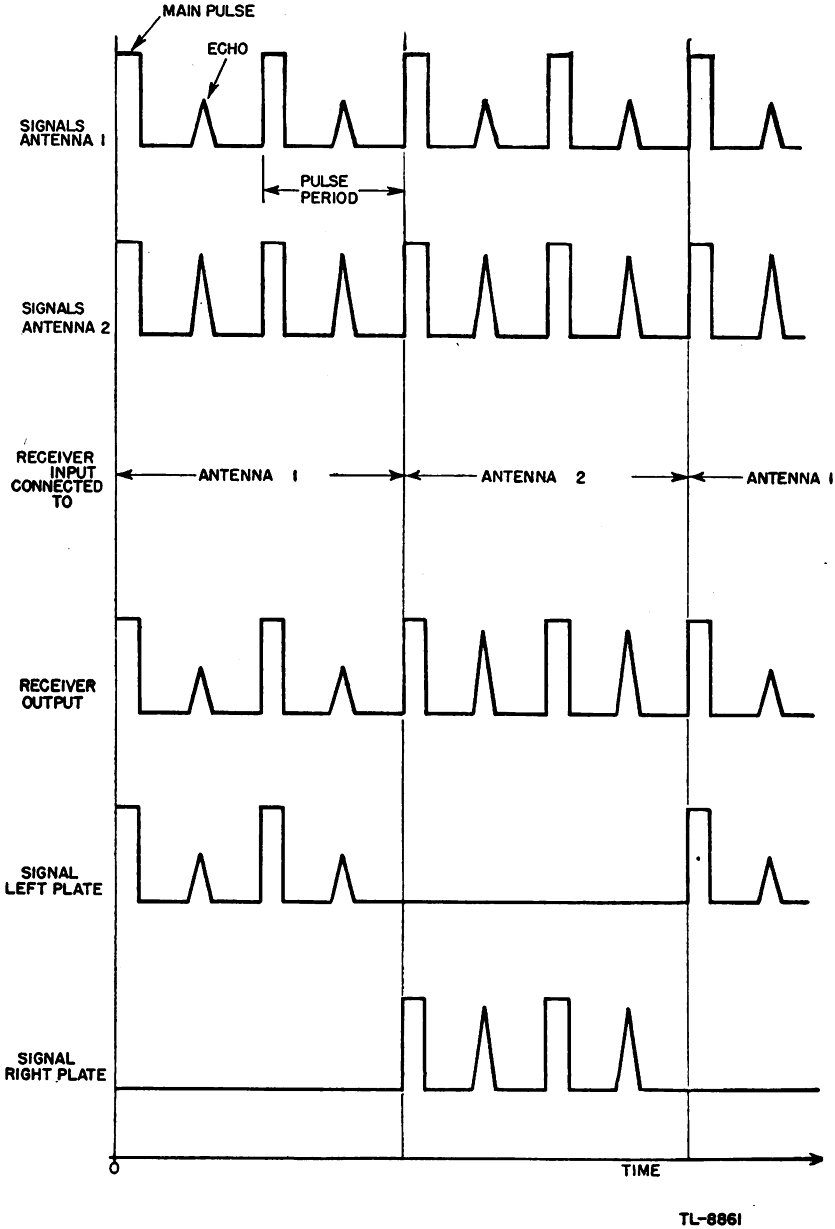

Figure 177. Lobe-switching waveforms.

adjusts the position of his antenna in azimuth until the pulses representing the target to be tracked cause equal deflection to right and left (fig. 179).

b. Single antenna, externally phased. (1) The two-antenna method of obtaining double lobes is simple and trouble-free, but is inefficient because only half of the available antenna

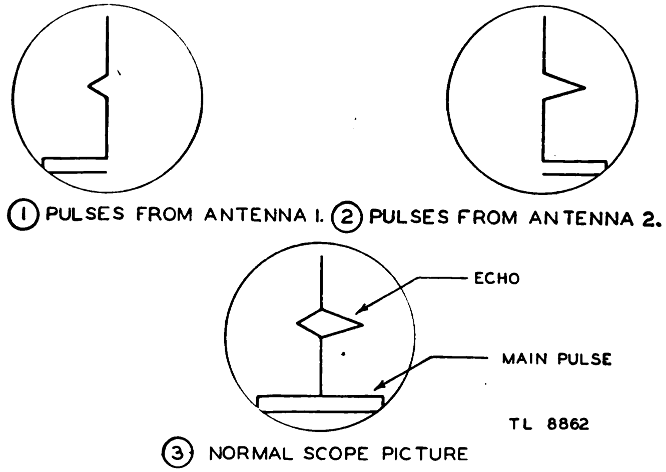

Figure 178. Normal scope picture.

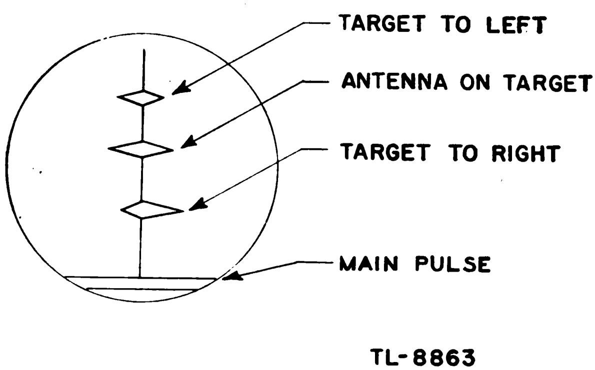

Figure 179. Effect of rotating the antenna.

space is used to receive echo signals at a time. The complete antenna can be used for receiving all signals by phasing one half of the antenna against the other half to produce a pattern whose axis is shifted first to the right and then to the left.

(2) In figure 180, an antenna four dipoles wide is used to receive echo signals from targets, and to measure their azimuth. The antenna is divided into a left half *A*, and a right half, *B*, connected by an external phasing section and feed line. A signal reflected

from a target at ① travels the same distance to reach A as it does to reach B. The r-f voltages induced in A are therefore in phase with those induced in B. The voltages of A and B travel toward each other over the phasing section, meeting and combining at the middle of the phasing section where the receiver feed line is connected. Since this junction is equidistant from A and B, the voltages are

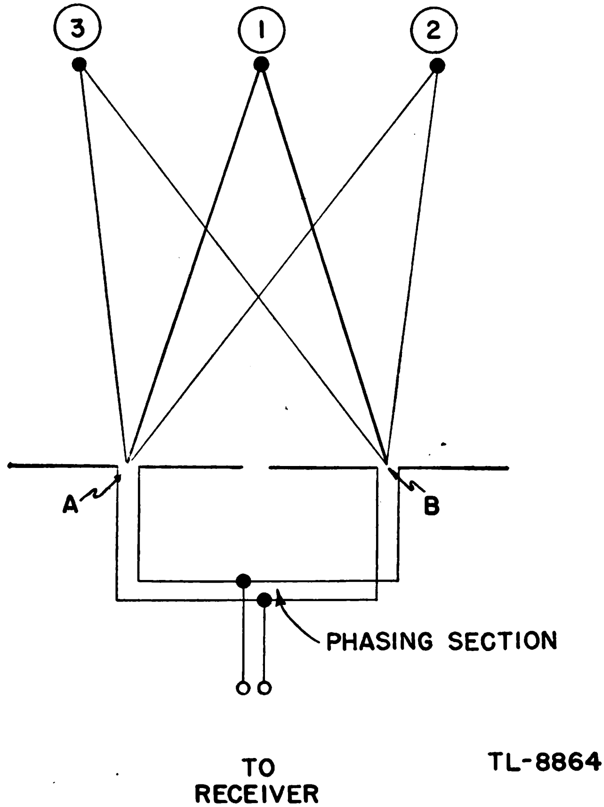

Figure 180. Echo signal paths to antenna.

still in phase and add directly to produce the voltage which reaches the receiver.

(3) If the target moves to ②, the echo signal reaches B first, and then travels on to A. The alternating voltages induced at A therefore lag behind those induced at B, and the instant of maximum voltage at A occurs after the maximum voltage at B. This is due to the greater distance between ② and A as compared to that between ② and B. The induced voltages travel over equal-length paths to reach the receiver feed line, so that their phase relationship remains the same as at the dipoles. The effective voltage which reaches the receiver from

the target at ② is less than that from the target at ① because of this phase difference (fig. 181).

(4) If the target is moved to ③ (fig. 180) the voltage induced at A leads that induced at B, and the voltage reaching the receiver is less than that produced by the target at ①. With the receiver feed

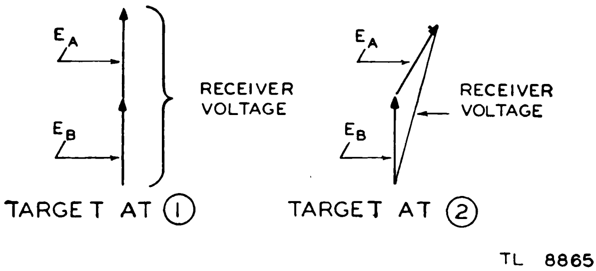

Figure 181. Phase addition of received signals.

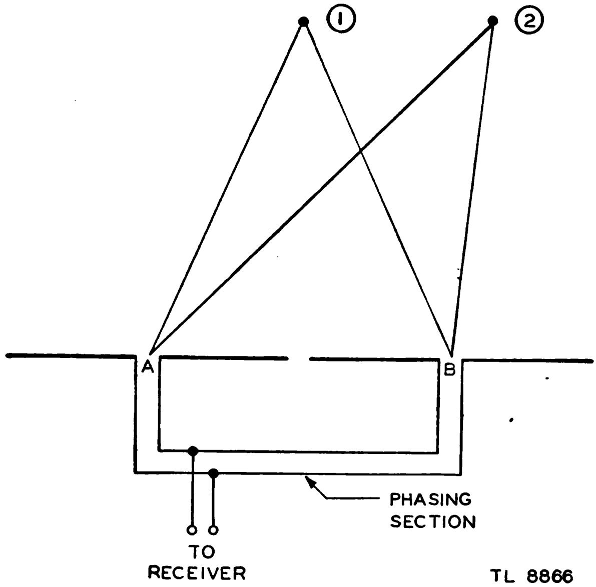

Figure 182. Off-center feed to receiver.

line connected to the center of the phasing section the target returns maximum signal only from ①.

(5) The difference in phase between the voltages from A and B can be controlled by varying the distance that each voltage travels in reaching the receiver feed line. In figure 182, the target is located at ② (fig. 180) and the receiver feed line is connected to the left of the center of the phasing section, so that the voltage from B travels further over the phasing section than the voltage from A. The addi-

tional path of travel for the voltage from *B* is made electrically equal to the additional path traveled in space by the echo signal in reaching *A*. The two voltages at the receiver feed line are therefore in phase, and add directly.

(6) If the feed-line connection is fixed, and the target is moved to ①, the voltages induced in the dipoles are in phase. When these voltages reach the receiver feed line, however, that from *B* lags that from *A*, and the signal which reaches the receiver is not maximum. Maximum receiver input voltage is produced only when the target is at ② when the receiver feed line is connected as shown.

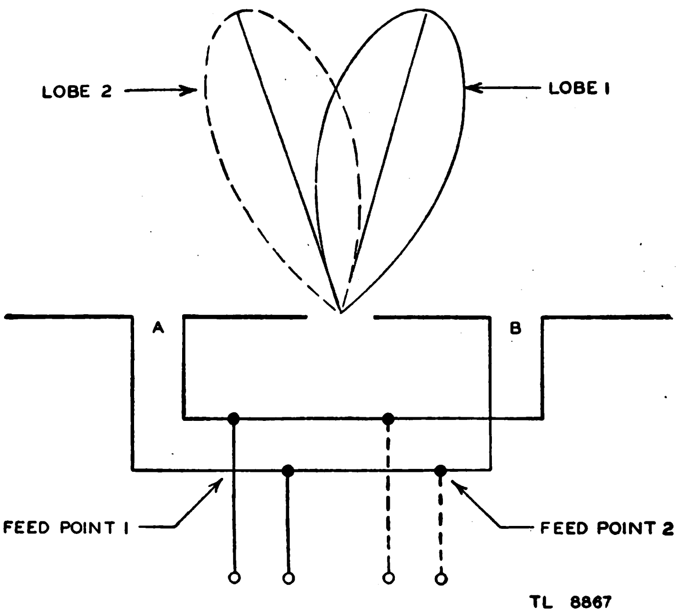

Figure 183. External phasing to produce double lobes.

(7) A field pattern of the antenna system with a phase delay introduced in the feed line to the right half, *B*, is shown in figure 183. The distance from feed point ① to *B* is less than a half-wavelength more than the distance to *A*. The phase delay thus introduced bends the pattern to the position of lobe ①. If the feed line is connected to feed point ② to produce the same phase delay in the path to *A*, a mirror image of lobe ① is obtained as shown by lobe ②. By alternating the point of connection a double lobe system is available for accurate azimuth measurement which uses the entire antenna for receiving each echo signal. The gain realized approaches twice that of a half section, and the beam width is reduced for more accurate bearings.

(8) The amount of phase delay introduced controls the positions of the double lobes. When the delay path-difference is greater than a

half-wavelength, the lobes are bent toward the feed point, rather than away, as in the example given.

(9) The problem of shifting the feed-point connection from one side of the antenna to the other is a difficult one to solve mechanically. The phase delay can be introduced electrically by placing a reactance across one of the branch feed lines. Figure 184 shows an antenna fed by a coaxial line which branches symmetrically to each half of the array. A half-wave line is placed across each branch line to act as a 1:1 transformer. The inner conductor of each line is terminated by

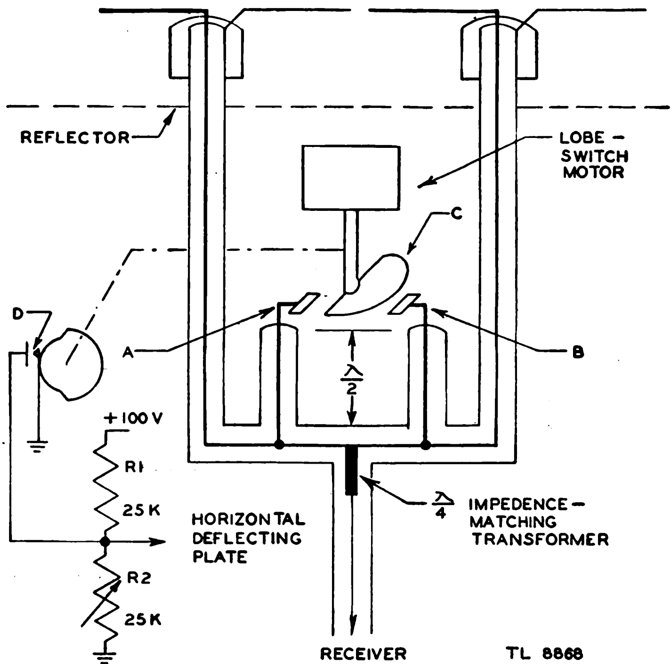

Figure 184. Reactance-phased double-lobe antenna.

a small plate of a capacitor, *A* and *B*. The other plate, *C*, is a half disk which is rotated by the lobe switch motor so as to engage each small plate for approximately one-half of a revolution.

(10) With disk *C* in the position shown, plate *A* is isolated and presents an open circuit across the left coaxial line. The open circuit is reflected down to the left branch line, and has no effect. The spacing between *B* and *C*, however, is such as to form a small capacitor which terminates the right coaxial line. This capacitance is reflected to the right branch, and is shunted across the line to increase the effective electrical length of the line. The result is to introduce a lag in the echo signals received by the right half of the antenna. As the lobe switch motor rotates the lag is placed alternately on the right

and left branches, and therefore causes the pattern of the antenna to shift from right to left.

(11) The signals are separated on the indicator screen by means of a variable position voltage controlled by a cam-operated switch. The cam is rotated by the lobe switch motor at the same rate as the capacitor disk *C*. The cam is shaped to close switch *D* during the time the lobe is bent to the left, and to leave the switch open while the lobe is bent to the right. Switch *D* shorts resistor R_2 when closed so that the positioning voltage to the indicator is zero. Resistor R_2 determines the voltage to the indicator when *D* is open.

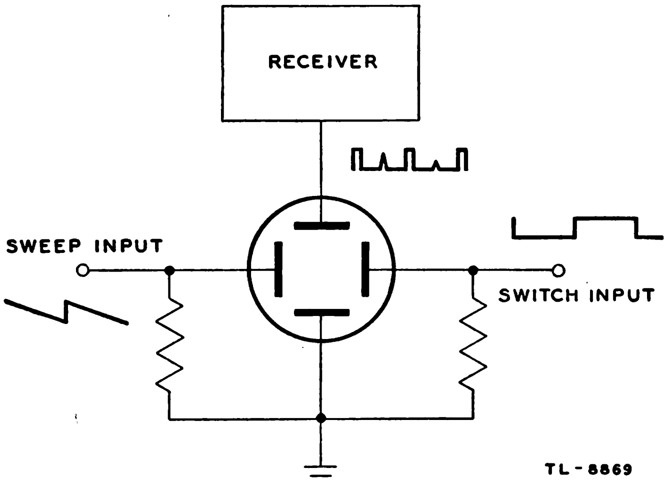

Figure 185. Indicator connections for echo separation.

(12) The output of the receiver consists of pulses from both lobes of the antenna array. These pulses are applied directly to the vertical deflecting plates of the indicator. The horizontal deflecting plates receive a saw-tooth sweep voltage synchronized to the PRF of the system, and the positioning voltage from switch *D* (fig. 185). With disk *C* near plate *B* (fig. 184), the lobe is bent to the right, and switch *D* is open. The positioning voltage is positive and causes the sweep trace to appear to the right of the center of the indicator to the left, and switch *D* is closed, shorting resistor R_2. The positioning voltage is zero, and the sweep trace appears to the left of the center line (fig. 186①). As the lobe switch motor rotates, the lobe and sweep trace are moved instantly from right to left, and left to right, building up a normal scope picture (fig. 186③). The amount of separation, or spread, between echo pips is controlled by resistor R_2, which can be adjusted to from 0 to +50 volts as the positioning voltage when switch *D* is open.

e. Single antenna, internally phased. (1) The antenna system just described provides either the left or the right lobe for receiving echo signals, depending on the position of the lobe-switching motor. Another choice of antenna system is available which produces both lobes simultaneously, and which uses electronic switching. The main advantage is to eliminate the switch contacts, and the noise resulting from dirt and incorrect adjustment of the contacts. The phasing is accomplished by an adjustable length line which connects the inner dipoles (fig. 187). A separate feed line is connected to each

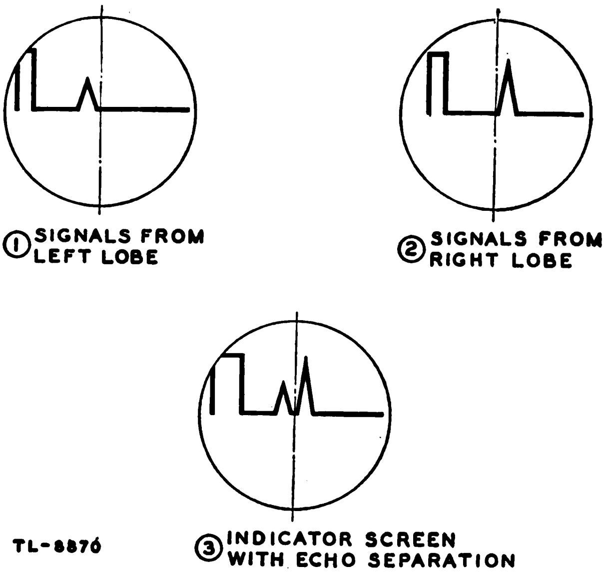

Figure 186. Echo separation on indicator screen.

half of the antenna. Each feed line runs to a separate input to the receiver.

(2) Echo signals arriving at the antenna array induce voltages which appear at *A* and *B*. The total voltage which reaches the receiver over feed line *A* is a combination of the voltage induced on *A* and that induced on *B* which travels over the phasing section to *A*. The phase of the voltage from *B* with respect to that at *A* depends on the path length from *B* to *A*, including the phasing section. The relative phase can therefore be controlled by varying the length of the phasing section.

(3) An echo signal received from a direction perpendicular to the face of the antenna induces in-phase voltages at *A* and *B*. This means that the induced voltage on the right feed point at *A* and the left feed point at *B* should be 180° out of phase. If the phasing section is of zero length the induced voltage at *B* travels one wave-

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length to reach A out of phase with the induced voltage at A, giving cancelation. Resetting the phasing section to have an over-all length of a half-wave produces a 1½-wavelength path, and the voltage from B arrives in phase with that of A to give a maximum. Setting the phasing section to add a length to the path from A to B which is other than an odd multiple of a half-wave makes the phase difference between the voltages such as to produce maximum signal at some direction other than straight ahead.

(4) Suppose that the echo signal is coming from a direction to the right of the perpendicular to the antenna (fig. 188). The signal induces a voltage at A which lags the voltage induced at B. By adjusting the phasing section to the correct length the voltage at B

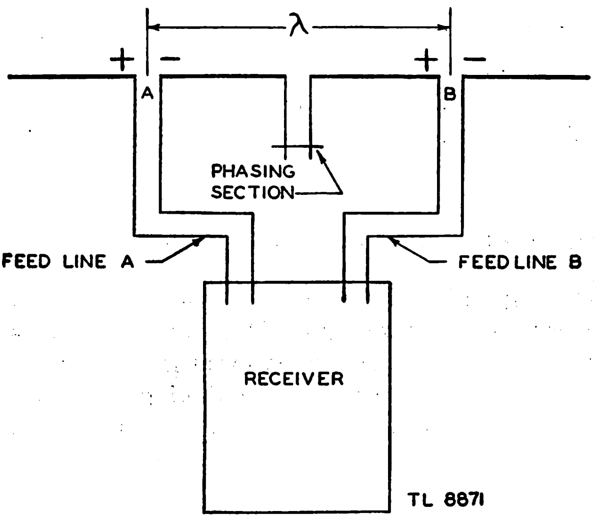

Figure 187. Internally phased double-lobe antenna.

can be delayed in reaching A to reduce the phase difference to zero. The two voltages at A will add in phase to produce a maximum. The voltage induced at A travels to B to produce a second available voltage for the receiver. The voltage from A, already lagging, receives an additional delay while traveling to B, so that the total voltage at B is not a maximum. In order to cause the receiver voltage at B to be a maximum, the target moves position to the left of the perpendicular. The second position of the target is at angle to the left of the perpendicular which is equal to the angle of the first position to the right.

(5) The use of the interval phasing section produces two lobes which are symmetrical about the perpendicular to the array. If the total length of path from A to B is between 1 and 1½ wavelengths, the lobe is bent away from the side of the antenna to which the feed line

is attached. If the length of path is between 1½ and 2 wavelengths, the lobe is bent toward the side to which the feed line is attached.

(6) In order to make use of the two lobes whose signals reach the receiver over separate feed lines, the receiver has two input channels and an electronic switch to select them alternately. The output of these channels is combined and applied to a conventional superhetero-

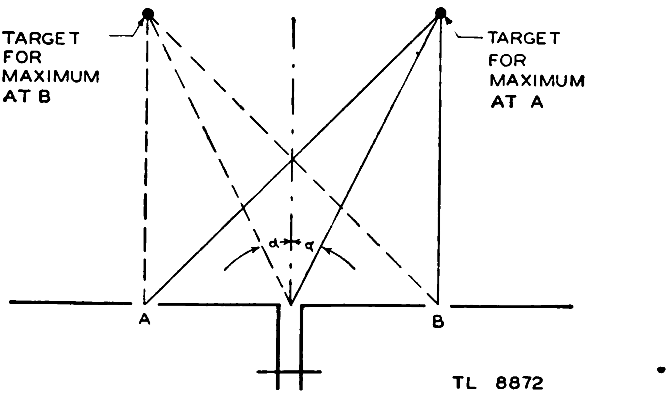

Figure 188. Adjusting phasing section for double lobes.

dyne receiver (fig. 189). The electronic switch produces two 1,000-cycle-per-second square-wave signals that are inverted with respect to each other. The signals are applied to the grids of the r-f amplifiers as blocking voltages. Since they are out of phase, r-f amplifier *A* conducts and amplifies while *B* is nonconducting. Every half cycle of the switching voltage this condition is reversed. Thus the signal

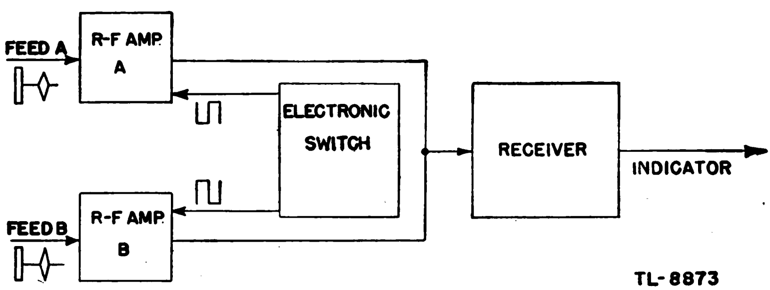

Figure 189. Block diagram of receiver with electronic switch.

applied to the single channel amplifier which comprises the rest of the receiver is alternately a signal from feed line *A* and than a signal from feed line *B*.

(7) Figure 190 shows the circuit diagram of a typical electronic switching system. Tubes V101 and V102 are duplicate r-f amplifiers for the signals appearing on feed lines *A* and *B* of figure 187. Trans-

former coupling is used for the input circuits to maintain a balanced feed-line system. The plate load circuit is common to both tubes, so that their outputs are combined as the input to the second r-f amplifier of the receiver. The grid of tube V101 is returned to ground through

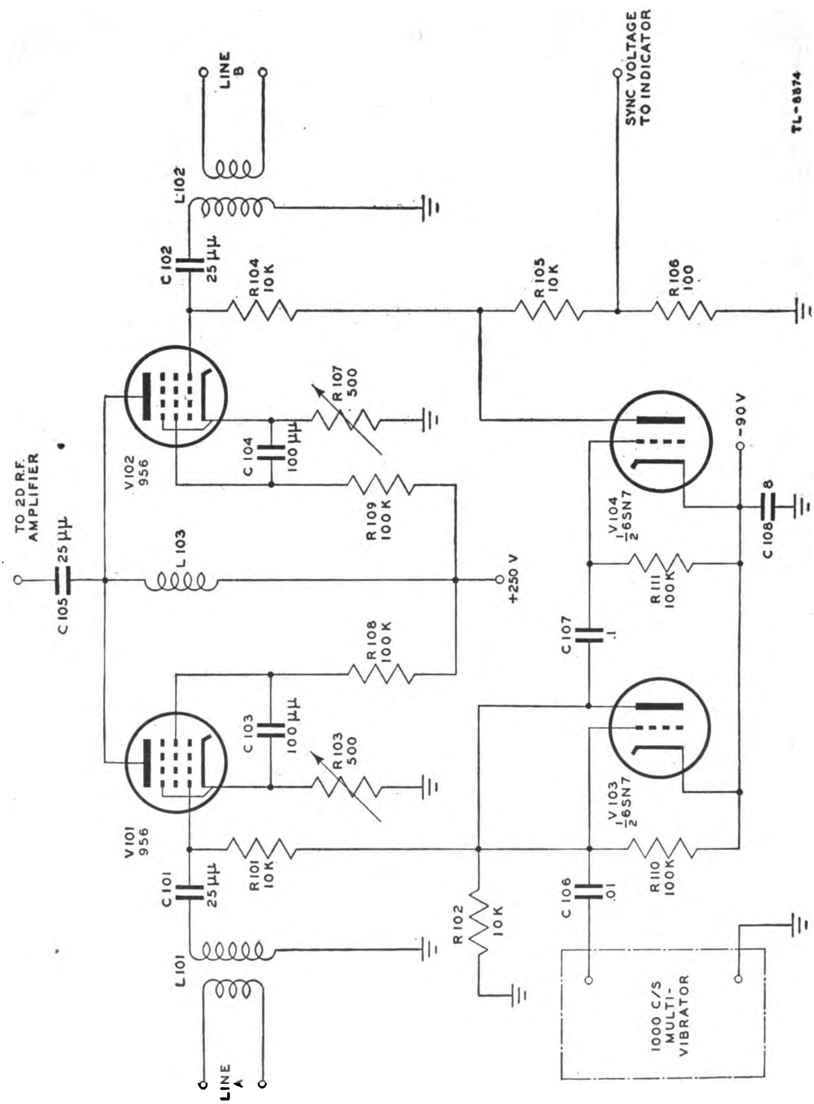

Figure 190. Circuit diagram of electronic switch.

resistors R101 and R102, the plate load of V103, the first switch amplifier. Similarly, the grid of V102 is returned to ground through resistor R104 and plate load of the second switch amplifier.

(8) The output of the 1,000 cycle-per-second multivibrator is an approximate square-wave of sufficient amplitude to overdrive tube

V103. This tube and V104 form a two-stage amplifier to further square the output of the multivibrator. The plate potential is caused to vary between ground and a negative value by applying a negative plate supply in the cathode instead of a positive one in the plate. Thus, when the output of the multivibrator swings to a positive maximum, tube V103 conducts, and the electrons flow from the plate to ground through resistor R102. This causes the plate to be negative with respect to ground. The negative voltage change across the plate load is coupled to V104, and cuts this tube off. Since there is no electron flow, there will be no voltage drop across R105 and R106, and the plate of V104 is at ground potential. As the output of the multivibrator swings negative, V103 is cut off, and its plate rises to ground potential, and a positive change is passed on to V104. V104 conducts and its plate voltage becomes very negative. Therefore, when the plate of V103 is at ground potential the plate of V104 is negative, and when the plate of V103 is negative, V104 is at ground.

(9) The grids of the r-f amplifiers are directly coupled to the plates of the switch amplifiers, so that the plate potential of V103 is a bias for V101, and that of V104 is a bias for V102. V101 operates as an amplifier with cathode bias when V103 is cut off, and is cut off when V103 conducts. V102 operates in the same manner with V104. Since V104 inverts the signal from V103, V101 and V102 alternate in operation. The signal developed across the common load inductor L103 is alternately the signal from feed line *A* and then from feed line *B*.

(10) The gains and plate currents of the two r-f amplifiers must be equal in order for the switching system to work correctly. Otherwise, the indicated equal signal position of the antenna will not correspond to the correct on-target position, and a square-wave modulation will appear in the output. This is taken care of by balancing the gains of the tubes, V101 and V102, with the individual gain controls, resistors R103 and R107. The indicator is similar to that described in the previous paragraph, and requires a square wave to mix with the sweep voltage for spreading the echo pips. This signal must be synchronized to the switching action, and is obtained by taking the voltage drop across resistor R106 in the plate circuit of V104. The receiver output is applied to the vertical deflecting plates of the indicator.

40. CONICAL SCANNING.

a. General. (1) The principle of lobe switching can be extended to give accurate azimuth and elevation simultaneously when applied to antenna systems using parabaloidal reflectors. The name given to this type of operation is conical scanning because an off-center lobe is produced which is rotated about the axis of the reflector

(fig. 191). The lobe axis describes a cone in space around the axis of the reflector.

(2) The echo signal received from a target which lies on the axis of the reflector has the same amplitude for all positions of the lobe. If the target moves away from the reflector axis the signal received varies approximately sinusoidally with the rotation of the lobe. As the axis of the lobe nears the target the signal increases, and as the axis of the lobe moves away the signal decreases. The relative phase of the signal variation therefore indicates the direction of the target from the reflector axis. The magnitude of the signal variation indicates the distance away from the reflector axis to the target.

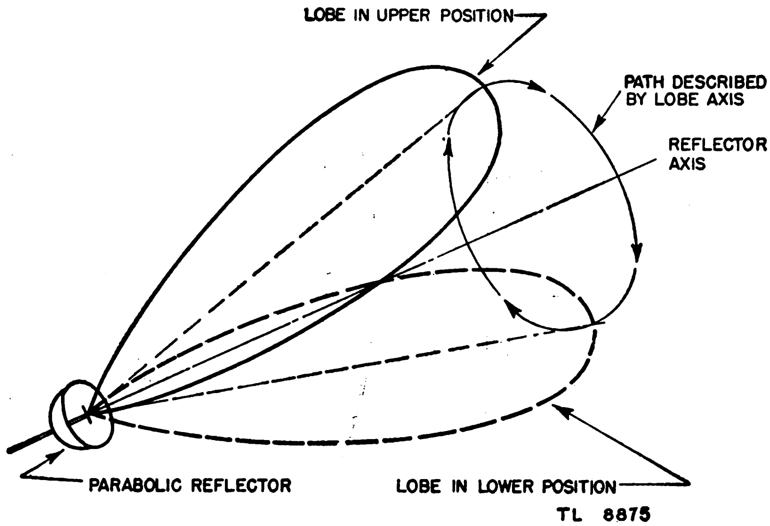

Figure 191. Conical scanning.

(3) Conical scanning is applied to microwave systems which are used for fire control against aircraft. The circuits which supply the indicator can be used simply to indicate the relative position of the target, or they can be made to track the target automatically as well as indicate its position. The discussion here will be confined to the methods for producing the conical scan.

b. Off-center dipole. (1) The simplest method to produce conical scanning is to use a coaxial line terminated in a dipole. The coaxial line is bent sufficiently to displace the electrical center of the dipole slightly away from the focal point of the reflector (fig. 192). The coaxial line and dipole are rotated by a scanning motor at a speed of 20 to 60 revolutions per minute.

(2) The apparent source of energy for the parabaloidal reflector is the electrical center of the dipole assembly. Since it is off center with

respect to the reflector, the lobe produced will be off center. As the center of the dipole rotates around the axis of the reflector, the lobe is rotated also.

(3) The chief disadvantage of the method illustrated above is that the dipole assembly is not balanced mechanically about the axis of rotation. A second method has been used in which the dipole assembly closely resembles that of the system described in section IV. The coaxial line is at the center of the reflector, and is perfectly straight

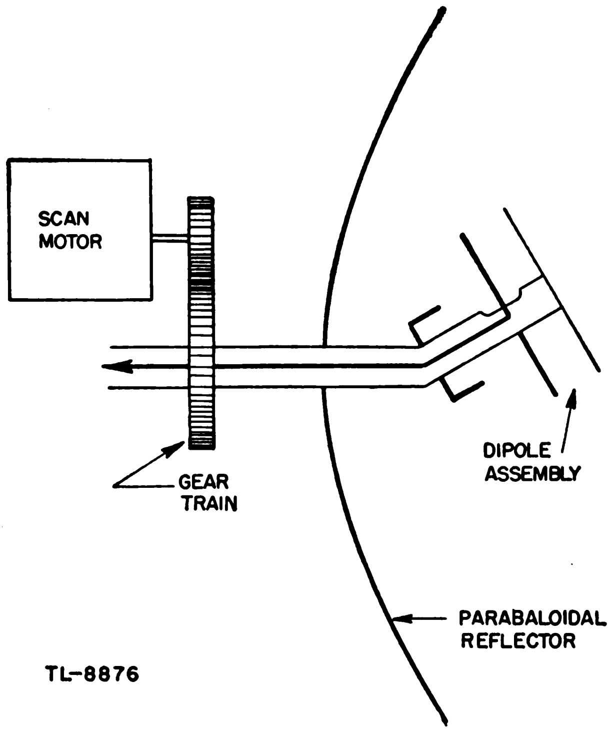

Figure 192. Off-center dipole.

and properly balanced. Figure 193 shows a dipole; elemant A is fed in the normal manner by direct connection to the inner conductor. The path for energy flow to element B is made longer by causing the energy to flow from the inside of the outer conductor through hole C and around the outside of the coaxial lines to element B. This manner of feeding, plus the position of the bazooka and the fact that the dipole elements are of different shape, gives an uneven current distribution. The uneven current distribution causes the electrical center of the dipole to move from the physical center. Therefore the energy is reflected from the paraboloid at a slight angle to the axis. As the dipole is rotated, the point at which the energy is directed describes

a circle around the center of the reflector and the reradiated energy describes a cone giving the desired conical scan. The bazooka or quarter-wave balancing section mounted on the outer conductor of the coaxial line also prevents standing waves on the transmission line.

c. Waveguide conical scan. (1) It is possible to produce a relatively simple system of conical scanning with a round waveguide

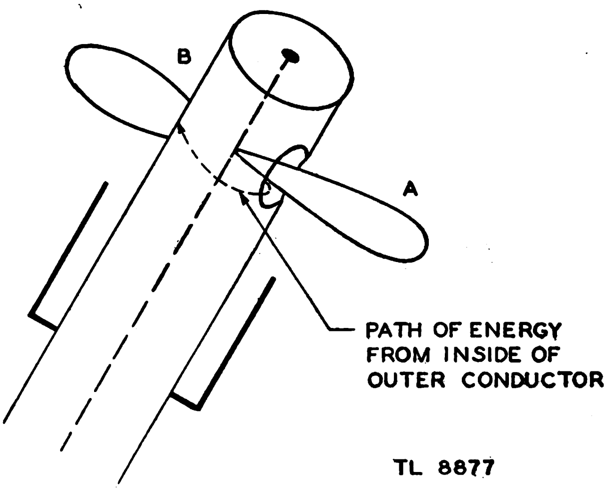

Figure 193. Construction of balanced conical-scan dipole.

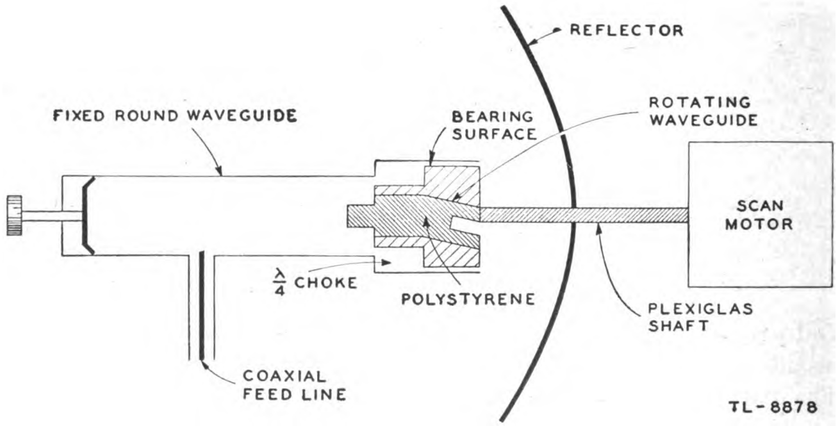

Figure 194. Conical scanning with waveguide.

which may easily be balanced mechanically. Figure 194 shows one type which is used. The r-f energy is supplied to a fixed round waveguide through a coaxial line. The inner conductor extends into the guide to act as the coupling probe, and a plunger in the end of the guide is used to adjust the degree of the coupling. A polystyrene-filled round waveguide is fitted in the other end of the waveguide.

(2) The inner end of the polystyrene is of the proper size to match the impedance of the fixed waveguide to that of the rotating waveguide. The rotating waveguide is bent off the center line of the fixed guide in order to produce a beam shift by supplying energy off center to the paraboloidal reflector. The conical scan is produced by driving the offset rotating waveguide through a plexiglass shaft coupled to the scan motor. A small hole in the outer end of the polystyrene filling helps to match the rotating waveguide to the paraboloid and to free space.

(3) The system can be balanced by properly distributing the weight of the metal plug in which the hole is bored to form the rotating waveguide. Radiation through the rotating joint between the fixed waveguide and the metal plug is prevented by a groove a quarter-wavelength deep, which acts as an r-f choke.

41. NONDIRECTIONAL ANTENNAS.

a. General. There are a few applications of radar and its associated equipment that require the use of nondirectional antennas. This type of antenna is used where a bearing indication is not neces-

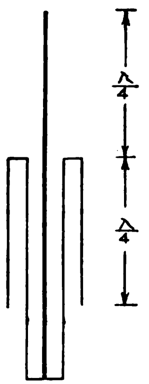

Figure 195. Vertical dipole fed with coaxial line.

sary or is undesirable. Nondirectional antennas are used in navigation aids such as beacons (Racon), some forms of IFF equipment, and in "presence" indicators, such as radar sets for submarines which indicate only the range of nearby aircraft.

b. Vertical dipole. (1) One of the simplest forms a nondirectional antenna can take is a single vertical radiator. It gives a uniform radiation pattern in the horizontal plane and a wide lobe in the vertical plane. Figure 195 shows one form of vertical dipole antenna fed by a coaxial line. The characteristic impedance of the line is designed to match the feed impedance of the antenna.